A Century of Astronomy.[1]

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The celebration of a centenary is an occasion for retrospect over the past and for hopeful outlook towards the future. We have here representatives of many different sides of astronomy who view it from many different aspects, and I should not be surprised if there are wide differences of opinion as to which are the outstanding landmarks in these hundred years. Like selecting the hundred best books, the selection of, let us say, the six great landmarks of astronomical progress in the century is a pastime which need not be taken too seriously. I shall venture to try my hand at a selection :—

(1) 1839. The first determinations of stellar parallax of 61 Cygni and α Centauri, giving for the first time a definite idea of the scale of the stellar universe.

(2) 1846. The discovery of Neptune. An event perhaps more highly celebrated outside astronomical circles than among professional astronomers, but producing an incalculable moral effect.

(3) 1864–68. The early spectroscopic discoveries of Huggins and Lockyer, and the rise of spectroscopic astronomy.

(4) 1882–87. The beginnings of stellar photography, starting with Gill's photograph of the great comet of 1882 and leading to the inception of the astrographic chart in 1887.

(5) 1904. Kapteyn's discovery of the two star-streams, the beginning of the modern era of investigations of the sidereal system.

Coming to events so near to the present that we cannot yet put much trust in our perspective, I would very tentatively include

(6) 1920. The measurement of the angular diameter of Betelgeuse by Michelson's interferometer method. I would not venture to predict how great or how immediate may be the influence of this last on the progress of astronomy; but it seems to me to be worthy of a place in this select list as a triumph of scientific achievement which is second to none. It is one of those signal instances which convince us that the word "impossible" must be banished from the vocabulary.

This is a record of continuous advance—not in great waves followed by periods of exhaustion. A new impetus has always been found before the last one has begun to fail. Even the allied science of physics has not, I think, had such a continuous record. I am told that there was a period shortly before X-rays and electrons came to the fore, when the physicist had given up anticipating any radical advance; he thought that the big discoveries were already garnered; and the feeling, so present with us to-day, that we are on the verge of something greater than our dreams can shape, had not yet disturbed his placid progress.

The centre of most rapid progress has shifted from time to time, and the various branches of astronomy have had their ups and downs. I suppose that in recent years the department of planetary astronomy has been in the depression of a wave. At least it seems to be so in comparison with the more sensational progress in our knowledge of the sun and stars. Whether we regard the physical observation of the surfaces of the planets or the study of their motions, the openings for advance seem to be few and difficult. But the depression has by no means reached stagnation. We have the remarkable advance in planetary photography, exhibited at several recent meetings of the Society; the discovery of new satellites, including Jupiter's two pairs of twins, and the specially significant phenomenon of the retrograde motion of the outermost satellites of Jupiter and Saturn; the determination of the rotation period of Uranus by Slipher; and the Trojan group of minor planets, the principal merit of which is that they have beneficently prevented the once great science of dynamical astronomy from growing altogether rusty. Renewed interest is added to the exact and regular observation of the positions of planets by Einstein's explanation of the anomalous motion of Mercury; the same observations reveal interesting irregularities in the longitudes of the planets which perhaps reflect inequalities in the rotation of the earth as standard time-keeper. These observations, which else might have seemed to be mere survivals of traditional routine, are seen to be full of importance for the future; and for the same reason we welcome the revival of observations of occultations of stars by planets. On the theoretical side, we have Taylor's important investigation of tidal friction in the Irish Sea, which, true to its name, is responsible for a considerable proportion of the friction and dissipation of energy on this planet; and Jeans's researches have given us new ideas of the origin of the planets which attend the sun, and of the singular (perhaps even unique) character of this system. Many other researches in this field could be mentioned. If the department of planetary astronomy is now the Cinderella of our science, she yet has dreams that her Prince is waiting for her.

It is startling to-day to read a passage from Huxley's "Essays" which runs :—"Until human life is longer and the duties of the present press less heavily, I do not think wise men will occupy themselves with Jovian or Martian natural history." Martian—and I almost fear to mention it—lunar natural history are no doubt thorny subjects, but notwithstanding Huxley's censure, probably the most sceptical among us would admit that the observation of seasonal changes of what is presumably some kind of vegetation on Mars is a recognised astronomical pursuit.

In reviewing the general advance of astronomy during the century, we cannot but be struck by what I may call its *centrifugal* tendency—the tendency to leave the little system ruled by the sun and penetrate deeper and ever deeper into the vast world outside. In the older books, the author leads us deliberately through the planets one by one, and it is with difficulty that the account of the stellar universe can be spun out to any respectable length. Before the first meeting of this Society in 1820 an introductory address was circulated, which contains the paragraph :

Beyond the limits of our own system, all at present is obscurity. Some vast and general views on the construction of the heavens, and the laws which may regulate the formation and motions of sidereal systems, have, it is true, been struck out; but, like the theories of the earth which have so long occupied the speculations of geologists, they remain to be supported or confuted by the slow accumulation of a mass of facts; and it is here, as in the science just alluded to, that the advantages of associated labour will appear more eminently conspicuous.

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[1] From the presidential address delivered before the Royal Astronomical Society on May 30.

While much obscurity still remains, this vast territory has been definitely annexed and occupied. From the planetary system we have passed to the stellar system; and I am not sure if even the study of that great aggregation of stars which we used to think was the whole universe is not becoming a little old-fashioned, and the really up-to-date young astronomer would refuse to bother about anything nearer than a globular cluster. At least it is one of the most startling features of recent research that so much exact knowledge has been obtained of the conditions of stars in globular clusters, not one of which is nearer than 10,000 light-years—knowledge which in many respects far surpasses in precision that which it has been possible to obtain for the much nearer denizens of our own star-cloud.

It may be of interest to examine how this centrifugal tendency is reflected in our Monthly Notices, and I have prepared a table to show how the subject-matter of the papers has changed. The figures claim no great accuracy, because it is often difficult to classify the papers clearly and uniformly; and, of course, the statistics do not distinguish important papers or long-continued observations from trivial notes and controversies. But on the whole the figures seem to be truly representative.

Classification of Papers in Monthly Notices, R.A.S.

	1840. (3 years.)	1860.	1880.	1900.	1919.	1920.
Instrumental . . .	6	4	11	3	6	5
Solar System . . .	39	69	73	56	14	21
Stellar universe. . .	18	13	22	21	49	40
Geodesy, navigation, seismology, etc. . . .	14	3	6	..	5	11
Ancient observations .	2	1	1	..	1	1
Mathematical (not classed above)	..	..	2	..	1	12
(Ditto, omitting ephemerides, tabular observations, etc., and formal reports of phenomena.)						
Solar system . . .	9	38	34	21	11	17
Stellar universe. . .	7	11	16	12	33	32

It appears that the serious change did not begin until after 1900. Although it shows itself quite suddenly in the statistics, it had been steadily prepared for during a long period. It must be remembered that much of the heaviest work on the stars is by its nature excluded from the Monthly Notices, and appears only in the more voluminous publications of observatories. Solar, lunar, and planetary observations are not usually too bulky to include. Much long-continued preparation for proper motions, spectral classification, radial velocities, stellar magnitudes, etc., began to come to fruition between 1900 and 1910. But I think the great impetus to sidereal astronomy came from Kapteyn's discovery, which I have mentioned among the six landmarks of the century. The two star-streams were the first taste of the many amazing results contained in the statistics collected or being collected. They were the first indication to us of something like organisation among the myriads of stars. Paradoxical as it may seem, the duality of the stellar system was the first clear indication to us of its unity. In the earlier years most of the papers classified in the table as referring to the stellar universe dealt with particular objects—variables, rapid binaries, Novae. It was a period of individualism. But from 1900 onwards the great democracy of the stars was brought into prominence, and a great wave of stellar socialism began. Kapteyn is the typical pioneer of a numerous body of investigators who view the heavens in the spirit of Xav erile Maistre in "Voyages autour de ma Chambre":

> The most brilliant stars have never been those which I contemplate with most pleasure; but the tiniest ones, those which, lost in immeasurable distance, appear only as barely perceptible points, have always been my favourite stars.

Yet perhaps in the very latest years there has been a reaction towards individualism. The statistical mill is no longer working overtime. The queer stars, such as Cepheids, runaway dwarfs, special binaries, are beginning to contribute more largely to the general perfection of the whole scheme. Strange objects which persist in showing a type of spectrum entirely out of keeping with their luminosity, may ultimately teach us more than a host which radiate according to rule.

It is noticeable that in the early years the disproportionate excess of papers on the solar system compared with the outside regions of the universe was not so marked as it afterwards became. This is no accident. The founders of the Royal Astronomical Society, while confessing almost complete ignorance of this domain, were resolved that it should be attacked, and had the conviction that patient research would make the advance possible. Indeed, it was just this which was placed among the most prominent reasons for banding together. With regard to eclipses, planets, and comets, it might be possible to struggle along individually; but the problems involving thousands of stars were too vast for one man or for one generation. They saw that the observations were being piled up, but without uniformity and without system. To quote again from their address:—

> One of the first great steps towards an accurate knowledge of the construction of the heavens is an acquaintance with the individual objects which they present: in other words, the formation of a complete catalogue of stars and of other bodies, upon a scale infinitely more vast than has yet been undertaken, and that shall comprehend the most minute objects visible in good astronomical telescopes. To form such a catalogue, however, is an undertaking of such overwhelming labour as to defy the utmost exertions of individual industry. It is a task which, to be accomplished, *must* be divided among members; but so divided as to preserve a perfect unity of design. . . . The intended foundation of an Observatory at the southern extremity of Africa, under the auspices of the Admiralty, may serve to show the general sense entertained of the importance of this subject, and the necessity of giving every possible perfection to our catalogue of the fixed stars. Deeply impressed also with the importance of this task, and fully aware of its difficulty, the Astronomical Society might call upon the observers of Europe and of the world to lend their aid in its prosecution. Should similar

institutions be formed in other countries, the Astronomical Society (rejecting all views but that of benefiting science) would be ready and desirous to divide at once the labour and the glory of this Herculean attempt, and to act in concert together in such manner as should be judged most conducive to the end in view.

It is largely the Herculean nature of the task before us which has led to astronomy being to-day (whether for good or ill) the most highly organised of the sciences.

The accomplishment of these objects has not been rapid. A passage in the First Annual Report of the Council mentions as one of the greatest desiderata a means of determining the apparent magnitudes of the stars, and ascertaining "a correct scale whereby astronomers may be enabled to express themselves in one common language on this subject." The lapse of a century has not quite sufficed for the completion of this uniform scale; but the main difficulties have been surmounted, and the time is very near now when all astronomers will be able to express themselves in a common language in regard to stellar magnitudes, both visual and photographic.

The foundation of our Society on January 12, 1820, caused a ripple in the aether which has spread out ever since in widening circles. To-day that ripple embraces about 5000 of the fixed stars. The remaining thousand million or so are still outside. Though a good many of the best-known stars must by this time have received the tidings, 90 per cent. of the naked-eye stars are still in ignorance. We should like to think that the stars of the morning sing together with joy on this our Centenary; but the cold truth must be faced that not 1 in 100,000 can yet have heard of our birth. But we shall look out on the heavens again to-night with renewed enthusiasm and joy; and if from the majority of the stars we can expect no more than an unrecognising stare, there are half-a-dozen old favourites which—we may fairly be persuaded—will give us an answering twinkle.

X-Ray Studies on the Crystal Structure of Iron and Steel.

AT the annual meeting of the Iron and Steel Institute last year, Dr. Westgren presented a paper on some X-ray crystallographic investigations on iron and steel. At that time the photograms on which his conclusions regarding the crystal structure of the steel components were based were not very clear, and were not published. Moreover, owing to spontaneous crystal growth at high temperatures, the photogram of gamma iron at 1000° C. did not show any continuous lines, but only a few spots. Since then, Dr. Westgren has continued his investigations and improved the experimental arrangements, and in a paper published with Mr. Phragmen at the corresponding meeting of the Institute on May 5 last, he showed photograms of very great interest and significance.

The X-rays were produced in a tube of the Seigbahn type. Difficulties had previously been experienced in obtaining vacuum-tight bronze tubes which composed the metal body. A more suitable material has been found in Skefko ball-bearing steel, which is remarkably free from slag inclusions and heterogeneities. The anti-cathode was cut off perpendicularly to its axis, and in order to get the characteristic X-rays of iron, which are very convenient for these investigations, an iron plate was soldered on to it. Round the radiating surface five windows were made. The tube therefore gave five beams, and exposures could be made in five cameras simultaneously. The tube was evacuated by the combination of a mercury vapour jet pump and a mercury diffusion pump of the Volmer type. Special arrangements were made for maintaining the vacuum of the desired quality. The tube was usually charged with 45,000-50,000 volts and run with 10-12 milliamperes.

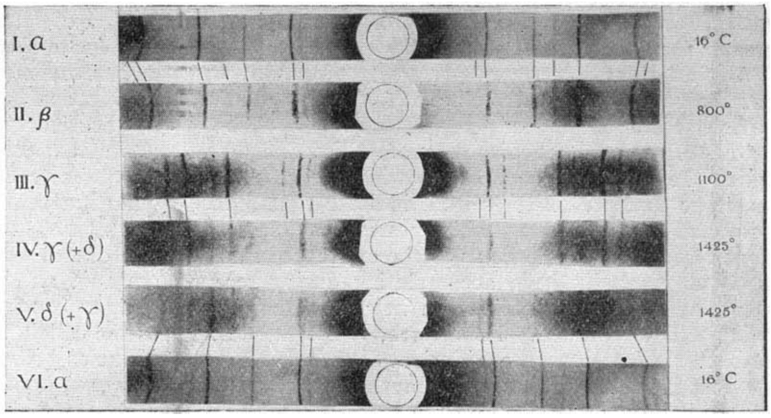

FIG. 1.

In investigating the crystal structure of pure iron at different temperatures, a wire (0·3 millimetre diameter) of vacuum-melted electrolytic iron containing 99·98 per cent. of the metal was investigated. Arrangements were made for rotating this three or four times per minute during exposures. Photograms were taken at the ordinary temperatures, and at about 800°, 1100° and 1425° C., which gave information of the structures of the iron in the alpha, beta, gamma and delta ranges (Fig. 1). The time of exposure was 2½ hours. The lines in the photograms obtained at the ordinary temperatures are clear and sharp, but in the higher ranges of temperature investigated they appear broad and not very distinct. The author explains this as due to the fact that the iron wire at temperatures of about 1400° C. is extremely pliable. Its position, therefore, changed somewhat during the exposure. Moreover, he found it very difficult to keep the temperature of the wire steady in the delta iron range. If the temperature was maintained at 1450° C., *i.e.* within about 70° of the melting point, the wire became so soft that it could not stand the torsion. The temperature, there-